**Supporting Information**

**Table S1. String codes for the literature search.**

String codes were created based on the different topics related to the research questions to extract information from the databases.

|  |  |  |
| --- | --- | --- |
| **String codes (Advanced search). Topic1: Protected areas, Andes and freshwater ecosystems** | Total | |
| Database | Web of Science | Scopus |
| protected area\*AND \*water\* AND ande\* | 103 | 99 |
| protected area\* AND south americ\* AND creation | 12 | 42 |
| protected area\* system\* AND south americ\* | 157 | 258 |
| national park\*AND ande\* AND\*water\* | 141 | 121 |
| eco\* corridor\* AND ande\* AND \*water\* | 108 | 19 |
| Total | 521 | 539 |

|  |  |  |
| --- | --- | --- |
| **String codes (Advanced search). Topic2: Mountain, Andes and freshwater ecosystems** | Total | |
| Database | Web of Science | Scopus |
| mountain\*AND \*water\* AND tropic\*ande\* | 144 | 116 |
| mountain\*AND tropic\* ande\*AND glacier\*AND stream\* | 14 | 9 |
| mountain\*AND tropic\* ande\*AND glacier\*AND lake\* | 18 | 9 |
| mountain\*AND tropic\* ande\*AND lake\* | 35 | 23 |
| mountain\*AND tropic\*ande\* AND stream\* | 42 | 34 |
| Total | 253 | 191 |

|  |  |  |
| --- | --- | --- |
| **String codes (Advanced search). Topic3: Protected areas, Andes and freshwater ecosystems** | **Total** | |
| Database | Web of Science | Scopus |
| Climat\* change\* AND tropic\* ande\* AND protected area\* | 13 | 12 |
| Climat\* change\*AND tropic\* ande\*AND protected area\*AND Adapt\* | 5 | 3 |
| Climat\* change\*AND tropic\* ande\*AND hydro\*AND Adapt\* | 14 | 9 |
| Climat\* change\*AND ande\* AND drought\* AND Adapt\* | 22 | 4 |
| Climat\* change\*AND ande\*AND\*water\*AND Adapt\* | 79 | 67 |
| Climat\* change\*AND ande\*AND\*water\* AND Adapt\*AND Soci\* | 29 | 29 |
| Total | 162 | 124 |

|  |  |  |  |
| --- | --- | --- | --- |
| **String codes (Advanced search). Topic4: Ecosystem services, Andes and water** | Total | | |
| Database | Web of Science | Scopus | |
| ecosystem\* AND service\*AND\*water\* AND ande\* | 75 | 80 | |
| ecosystem\* AND service\*AND\*water\* AND ande\*AND Biodivers\* | 97 | 27 | |
| ecosystem\* AND service\* AND\*water\* AND ande\*AND Biodivers\*AND Descompos\* | 1 | 0 | |
| ecosystem\*AND service\* AND\*water\* AND ande\*AND Biodivers\*AND agricul\* | 1 | 5 | |
| Total | 174 | 112 | |
| **String codes (Advanced search). Topic 5: Stream connectivity biodiversity and human impact** | Total | |
| Database | Web of Science | Scopus |
| stream\*AND connect\* AND ande\* | 29 | 22 |
| stream\*AND connect\*AND ande\*AND protected area | 0 | 0 |
| protected area\* AND impact\* AND ande\* AND \*water\* | 11 | 12 |
| protected area\* AND impact\* AND tropic\* ande\* AND \*water\* | 1 | 0 |
| Total | 41 | 34 |

**Table S2.** Selected literature based on research questions and key topics about freshwater ecosystems and PAs in the tropical Andes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Question** | **Topic** | **Number of publications and database sources** | **Key References** | |
| **Question 1** | **Creation of PAs in the tropical Andes** | * 10 research articles. * 13 management plans from Governmental Institutions. | **National PAs**  - Messerli, et al (1997)  - Young (1993)  - Rundel & Palma (2000)  - Redondo-Brenes (2009)  - Hoffmann & Oetting (2011) | **Local PAs**  - Montoya-Zumaeta et al. (2019)  - Ostovar et al. (2019)  - Iniguez Gallardo et al. (2013)  - Joslin (2020)  - Leroy (2019) |
| **Question 2** | **Freshwater ecosystems** | * 13 research articles. * 3 databases: Hydrosheds (rivers, catchments and lakes), GLIMS (glacier cover and glacier lakes), and Global Multi-Decadal Glacial Lake Inventory. * 31 Ramsar sites. | **Lakes**  - Mosquera et al. (2017)  - Polk et al. (2017)  **Rivers and watersheds**  - Thieme et al. (2017)  **Ramsar sites**  - Jara et al. (2019)  - Chimmer et al. (2019  - Otto & Gibbons. (2017)  - Yager et al. (2019).  - Wittman et al. (2015).  - Ibanez Blancas et al. (2018) | **Climate-related impacts**  - Cook et al. (2016)  - Colonia et al. (2017)  - Drenkhan et al. (2018)  - Pilco Zolá et al. (2019) |
| **Question 3** | **Aquatic biodiversity** | * 8 research articles * 1 IUCN report | -Tognelli et al. (2016)  - Lessmann et al. (2016)  - Nieto et al. (2017)  -Tognelli et al. (2019)  - Labaj et al. (2017, 2018a,2018b) | **Climate-related impacts and fragmentation of river connectivity**  -Herrera et al. (2020)  - Anderson et al. (2018) |
| **Ecosystem services** | * 6 research articles * 1 Report | - Rincón et al. 2017  - Vila et al. 2007  - Hribljan et al. (2015, 2016)  -Planas-Clarke et al. (2020)  - Brown (2005)  - Ramos & Armenteras (2010) |  |

**Table S3.** Objectives of creation and management plans of PAs in the tropical Andes. *Servicio Nacional de Área Protegidas* (SERNAP), *Sistema Nacional de Áreas Protegidas* (SNAP), *Sistema Nacional de Áreas Naturales Protegidas por el Estado* (SINANPE), *Registro Nacional de Áreas Protegidas* (RNAP), and *Sistema Nacional de Áreas Protegidas* (SINAP) are the national systems of PAs for each country in the tropical Andes.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **PA** | **Objectives of creation/in the management plan.** | **Source** |
| **Water resources in the objectives of the PA creation** | Cordillera del Sama Biological Reserve (Bolivia). | (1991). Watershed conservation to supply drinking water to Tarija city and nearby communities. | SERNAP (2020)  Management Plan for Cordillera de Sama (2004) |
| Tunari National Park (Bolivia) | (1979). Hydrological resources protection and forest conservation. | SERNAP (2020) |
| Sajama National Park (Bolivia) | (1939). Polylepis forest conservation. The new conservation objectives established in 1995 included headwaters conservation for maintaining water sources quality and quantity | SERNAP (2020)  Management Plan for Sajama National Park (2001) |
| Podocarpus National Park (Ecuador) | (1983). Podocarpus and Chinchones forest protection and freshwater ecosystems such as lakes and rivers for recreation and environmental education. | SNAP (2020)  Management Plan for Podocarpus National Park (2014) |
| Río Abiseo National Park (Perú). | (1983). Humid forest, biodiversity, and maintenance of the hydrological stability of catchments. | SINANPE (2020)  Master Plan for Abiseo National Park (2007) |
| Ichigkat Muja-Cordillera del Condor National Park (Perú). | (2007). Created for its high biological and geological values, and protection of headwaters of the Cenepa and Comaina river basins, tributaries of the Santiago River, and ecological functions in the water cycle of Marañón basin. | SINANPE (2020)  Master Plan for Ichigkat Muja-Cordillera del Condor National Park (2016) |
| Lauca National Park (Chile). | (1965). Created as Forest Reserve, and later elevated as National Park in 1970 with a subsequent decree in 1989 that prohibited mine activities nearby lakes. | RNAP (2020) |
| **Water resources in the objectives of the Management Plans** | Sangay National Park (Ecuador) | (1979). Unclear objectives of creation, but management plan points toward conservation of wetlands and hydrological resources for hydroelectric projects. | SNAP (2020)  Management Plan for Sangay National Park (1998) |
| Cajas National Park (Ecuador) | (1977). Created for recreation and tourism. Management plan targets the freshwater conservation. | SNAP (2020)  Management Plan for Cajas National Park (2018) |
| Puracé National Park (Colombia) | (1961). Unclear objectives, but management plan aims to protect micro and macro catchments by creating areas of conservation and has the main goal of obtaining a Ramsar designation. | SINAP (2020)  Management Plan for Puracé National Park (1996). |
| Los Guácharos National Park (Colombia) | (1960). Conservation of caves with high geological and ecological value. Plan highlights the protection of the Suaza River and two main tributaries. | SINAP (2020) Management Plan for Guácharos National Park (2009) |
| Huascarán National Park (Perú) | (1975). Declared a Biosphere Reserve by UNESCO in 1985. Covers the most extensive part of the tropical mountain range of Cordillera Blanca, and hosts many glaciers and glacial lakes. | SINANPE (2020)  Master Plan for Huascarán National Park (2007) |
| **PA with high value for Mountains** | Nevado del Huila National Natural Park (Colombia). | (1977). Biodiversity conservation, created for its landscape, geomorphological, cultural and scientific values. | SINAP (2020)  Management Plan for Nevado del Huila (2011) |
| Campo de los Alisos National Park (Argentina) | (1995). Unclear objectives, but management plan aims to protect Las Pavas and Jaya watersheds, as well as biodiversity across altitudinal gradient of the east side of the Nevados del Aconquija | Administración de Parques Nacionales (2020)  Management Plan for the Los Alisos National Park (2016) |
| Apolobamba National Park (Bolivia) | (1972) National Reserve, later elevated as National Park in 2000. It covers the Chaupi Orco glacier as the highest peak (6044 m). The management plan includes sub-programs for wetlands, water quality, and hydrological characterization. | SERNAP (2020)  Management Plan for Apolobamba National Park (2006) |
| Tuni-Condoriri National Park (Bolivia) | (1942). No management plan initiated. This Park covers the Chacaltaya and Huayna Potosí mountains and Tuni Lake, which are the main water source for millions of people living in La Paz and El Alto. | Hoffmann & Oetting (2011) |

**Table S4:** IUCN categories definitions obtained from Dudley et al. 2013

|  |  |  |  |
| --- | --- | --- | --- |
| **IUCN category** | **Definition** | **IUCN category** | **Definition** |
| **Category Ia**  **(Strict nature reserve)** | Protected areas are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring. | **Category V (Protected landscape/seascape)** | A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values. |
| **Category Ib (Wilderness area)** | Protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition. | **Category VI (Protected area with sustainable use of natural resources)** | Protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area. |
| **Category II (National Park)** | Protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities. | **Not applicable** | This currently applies to World Heritage Sites and UNESCO MAB Reserves. It applies to a site that does not fit the standard definition of a protected area. |
| **Category III (Natural monument or feature)** | Protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value. | **Not assigned** | The protected area meets the standard definition of protected areas but the data provider has chosen not to use the IUCN Protected Area Management Categories. |
| **Category IV (Habitat/species management area)** | Protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category. | **Not reported** | For protected areas where an IUCN category is unknown and/or the data provider has not provided any related information. |

**Figure S1:** Schematic representation of the literature review process.



**Figure S2: PAs in the tropical Andes.**  a) PAs in the tropical Andes based on the IUCN categories. b) Boxplots of the surface area of each PA category. Boxplots indicate upper and lower quartiles of the surface values. The line in the box represents the median, the open circles are the whiskers extending up to 1.5 times the respective quartile. c) Number of PAs in each IUCN category.



**Description:** there were a total number of 1,330 of PAs in the tropical Andes. PAs covered 32.8% of the total surface of the tropical Andes (1,550,538.8 km2). 0.01%, 8.20%, 0.33%, 0.58%, 3.18%, and 5.03 % of the surface area were under the *Ia, II, III, IV, V* and *VI* IUCN categories of protection, respectively. The 4.24%, 0.08%, and 11.15 % of the surface area were under no IUCN category of protection (the not applicable, assigned and not reported classifications). Figure S2a shows a map of the overall PAs in the tropical Andes and the IUCN categories. Figure S2b shows boxplots of protected surface areas by each category. Those areas that were not applicable for protection had the largest surface areas in the Andes reaching a maximum value of 17,162.95 km2. Strong protection categories reached a surface area of around 5,000 km2. Figure S2c shows the number of PAs for each category. There are three and 970 PAs under the categories (Ia) and VI, respectively.

For the present study, only IUCN categories from I to IV were selected, as they represent the highest protection levels, and most of them are under the national governance. When selecting such categories, all PAs from Ecuador and Bolivia were under the *Not reported* classification (149 PAs, Figure S1c). Thus, for these countries, PAs under the national systems were selected: Servicio Nacional de Areas Protegidas (SERNAP) for Bolivia and the Sistema Nacional de Área Protegidas SNAP for Ecuador.

**Figure S3. Selecting PAs.**  a) PAs selected based on the IUCN categories and the national systems of PAs for Bolivia and Ecuador. b) Boxplots of the surface area of each PA category. Boxplots indicate upper and lower quartiles of surface area values. The line in the box represents the median, the open circles are the whiskers extending up to 1.5 times the respective quartile, c) Number of PAs in each IUCN category.



**Description:** the 189 PAs have a surface area of 232,864.3 km2 (15.01% of the total tropical Andes). 0.01%, 8.20%, 0.33%, 0.58%, 3.18 % of the surface area were under the *Ia, II, III, IV IUCN* categories, and 5.8% was under the national systems of PAs for Bolivia and Ecuador (SERNAP/SNAP). Figure S3b shows boxplots of protected surface areas by each category. Category *Ia* included a surface area of around 120 km2, and category II included surface areas of 1,712 km2. Figure S3c shows the number of PAs in each category.